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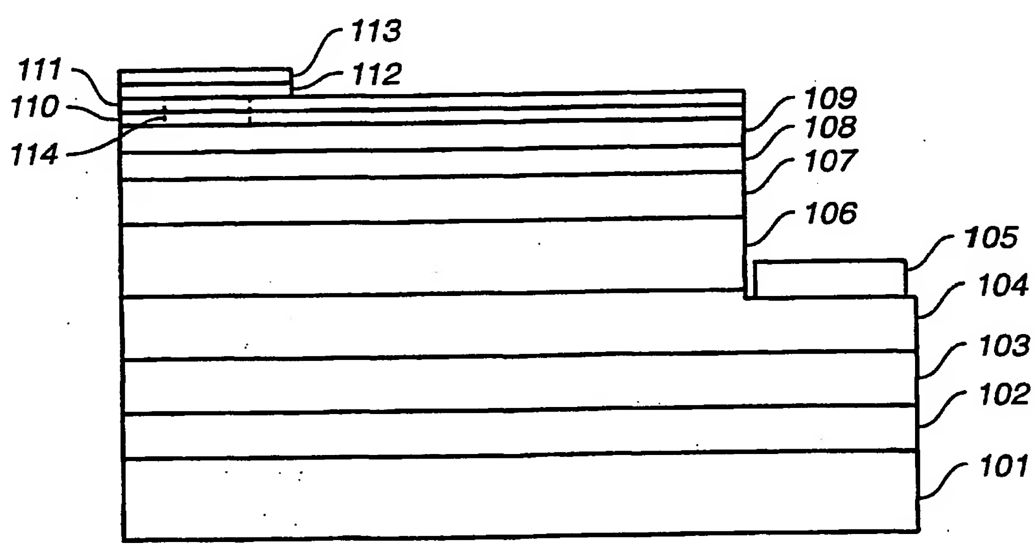
(54) Title: IMPROVED WINDOW FOR GaN LED



(57) Abstract: A window structure for Gallium Nitride based Light Emitting Diode comprises: an Mg+ doped P window layer (109) of GaN compound; a thin semi-transparent metal contact layer (110); an amorphous current spreading layer (111) formed on the contact layer. The contact layer is formed of NiOx/Au; and the current spreading layer is formed of Indium Tin Oxide. The P electrode (112) of the diode comprises a titanium adhesion layer which forms an ohmic connection with the current spreading layer and a Shottky diode connection with the Mg+ doped window layer.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

TITLE

Improved Window for GaN LED

TECHNICAL FIELD

This invention relates to GaN based Light Emitting Diodes (LED)

BACKGROUND OF THE INVENTION

A semiconductor light-emitting diode (LED) comprises: a substrate; a light emitting region; a window structure and a pair of electrodes for powering the diode. The substrate may be opaque or transparent. Light Emitting Diodes which are based on Gallium Nitride compounds generally comprise: a transparent, insulating substrate, e.g. a sapphire substrate. With a transparent substrate, light may be utilized from either the substrate or from the opposite end of the LED which is termed the "window".

The amount of light generated by an LED is dependent on the distribution of the energizing current across the face of the light emitting region. It is well known that the current flowing between the electrodes tends to concentrate in a favored path directly under the electrode. This tends to activate corresponding favored portions of the light emitting region to the exclusion of portions which fall outside the favored path. Further since such favored paths fall under the opaque electrode, the generated light reaching the electrode is lost. Prior art GaN LEDs have employed conductive current spreading layers formed of Ni/Au; and have mounted a Au window bond pad on such layers. In such arrangements, the Ni/Au layer and or the Au bond pad tend to peel during wire bonding to the pad.

DISCLOSURE OF THE INVENTION

In accordance with the present invention, light is utilized at the output of the window structure which comprises: a very thin, semi-transparent NiO_x\Au contact layer formed on a P doped Nitride compound window layer; a semi-transparent amorphous conducting top window layer; and a P electrode structure formed of a titanium layer with a covering Au bond pad. The amorphous

top layer, by way of example, may be formed of: Indium Tin Oxide (ITO); Tin Oxide (TO) or Zinc Oxide (ZnO). Layers of other amorphous, conductive and semi-transparent oxide compounds also may be suitable for construction of the top window layer.

Advantageously, the thin NiO_x\Au layer provides an excellent ohmic connection to both the amorphous current spreading conducting layer and to the Mg doped GaN window layer; the highly conductive amorphous layer efficiently spreads current flowing between the electrodes across the light emitting region to improve the efficiency of the device.

Additionally, the titanium electrode passes through both the amorphous conducting layer and the underlying Ni/Au to: (a) form an ohmic contact with those layers; (b) contact the P doped top window layer and form a Shottky diode connection therewith; and (c) provide good adhesion between Ti and the Mg doped window layer. The Shottky diode connection forces current from the electrode into the amorphous conducting layer and eliminates the tendency of the prior art structures to concentrate current in a path directly under the electrode.

BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 schematic showing of the side view of an illustrative embodiment of our improved LED.

DETAILED DESCRIPTION

The illustrative LED of Fig. 1 is a GaN based device in which light exits through window 109.

The LED of Fig. 1 comprises: sapphire substrate 101; buffer region 102, GaN substitute substrate layer 103; N cladding layer 104, active region 106, P cladding layer 107, window layers 108, 109, N electrode 105, and the window structure which comprises thin NiO_x\Au semi-transparent layer 110, semi-transparent amorphous conducting layer 111, titanium electrode 112 and bond pad 113.

Layers 101 through 104, and layers 106 through 109 are grown in a Metal

Organic Chemical Vapor Deposition (MOCVD) reactor. The details of MOCVD growth of the stated layers are well known in the industry and will not be discussed herein.

The remaining components of the illustrative LED, namely, layers NiO_x\Au layer 110, amorphous conducting layer 111; N electrode 105, and P electrode 112 and 113 are formed by evaporation in apparatus other than a MOCVD reactor. Such processes are well known in the prior art and are not described herein.

Light emitting structure

The illustrative light emitting structure of Fig. 1 comprises N cladding layer 104, active region 106, and P cladding layer 107. Layer 104 is formed of Silicon doped GaN.

In the illustrative example of Fig. 1, active region 106 is a Silicon doped N type GaInN/GaN Multi Quantum Well (MQW) structure. Other forms of active regions may be utilized with our improved window structure.

P cladding layer 107 is formed of Mg doped AlGaN.

Window layers

The first window layer 108 is formed of Mg doped GaN. Layer 108 has a nominal thickness of 300nm. The second window layer 109 is similarly formed of Mg doped GaN. However, layer 109 is more highly doped to permit an ohmic contact between that layer and the very thin NiO_x\Au layer 110.

Completion of the MOCVD growth process

Growth of P type GaN layers is achieved with introduction of gaseous flows of TMG with H_2 as a carrier gas, NH_3 as a group V material, and Mg as a dopant. In the absence of an appropriate cool down protocol, Hydrogen passivation of the Mg may occur. In which case, the conductivity of a Mg doped layer is reduced.

In order to avoid Hydrogen passivation of the Mg doped layers 107, 108 and 109, the following described cool down protocol has been adopted upon completion of the MOCVD growth.

1. The ambient gas of the reactor is switched from H_2 to N_2 immediately after completion of the LED structure;
2. The reactor temperature is ramped down from the growth temperature to about 900 degrees C in about 2 minutes;
3. The flow of NH_3 is terminated;
4. The reactor temperature is further ramped down to about 750 degrees C in about 2 minutes;
5. Temperature of about 750 degrees C is held for about 20 minutes;
6. The heater of the reactor is shut off and the reactor is allowed to complete cool down naturally. Experience shows that cool down to 120 C occurs in about 30 minutes after heater shut off.

The resulting product exhibits the expected desired physical and electrical characteristics.

Formation of the electrode structures

Fig. 1 illustrates the locations of both P electrode layers 111, 112 and of N electrode 105.

Layer 110 is a very thin, semi-transparent contact layer of NiO_x\Au which is deposited over the entire exposed face of layer 109. Opening 114 is formed in layers 110 and 111 to permit deposit of titanium adhesion layer 112 to contact window layer 109. Titanium forms a strong physical bond with layer 109 and thus tends to eliminate peeling during wire bonding. In addition to reaching through to layer 109, titanium structure 112 is deposited through and on top of amorphous layer 111. Titanium electrode 112 forms ohmic contacts with layers 110 and 111; and forms a Shottky diode contact with layer 109. The Shottky diode connection to window layer 109 eliminates the current path directly under the electrode and forces current flowing between the electrodes into conducting layer 111.

P electrode Au bond pad 113 is deposited on top of titanium layer 112 to form an ohmic contact.

Since the Mg doped layers do not suffer from Hydrogen passivation, it is not necessary to heat treat the structure to activate the Mg doping in those layers. However, Ni/Au layer 111 and the Ti and Au contact structures are heated in an

atmosphere of molecular nitrogen and air. Thus the Ni is converted to a form of nickel oxide. The described heat treatment improves the quality of the contact structures.

The invention has been described with particular attention to its preferred embodiment; however, it should be understood that variations and modifications within the spirit and scope of the invention may occur to those skilled in the art to which the invention pertains.

What is claimed is:

(1) A light emitting diode comprising a substrate, a light emitting region, a window structure; and first and second electrodes, wherein: said window structure comprises: a thin, semi-transparent metal contact layer, and a semi-transparent, conductive amorphous current spreading layer formed directly on the exposed face of said contact layer.

(2) A light emitting diode in accordance with claim 1 wherein: said contact layer is a NiO_x\Au layer.

(3) A light emitting diode in accordance with claim 1 wherein: said amorphous current spreading layer is formed of Indium Tin Oxide.

(4) A light emitting diode in accordance with claim 2 wherein said amorphous current spreading layer is formed of Indium Tin Oxide.

(5) A light emitting diode in accordance with claim 1 wherein: said window structure comprises: an Mg + doped window layer; said Ni/Au contact layer is formed on said Mg+ doped window layer; said first electrode forms an ohmic connection with said current spreading layer.

(6) A light emitting diode in accordance with claim 5 wherein: said first electrode forms a Shottky diode connection with said Mg + doped window layer.

(7) A light emitting diode in accordance with claim 5 wherein: an opening is formed through said contact layer and said current spreading layer; said first electrode comprises a layer of titanium formed on said current spreading layer and through said opening to contact said Mg+ doped window layer.

(8) A light emitting diode in accordance with claim 2 wherein: said contact layer comprises a Ni oxide/Au layer.

(9) A light emitting diode comprising a substrate, a light emitting region, a window structure; and first and second electrodes, wherein: said window structure comprises: an Mg + doped window layer, a thin, semi-transparent NiO_x\Au contact layer formed on said Mg+ doped window layer; and a semi-transparent, conductive amorphous current spreading layer formed of ITO directly on the exposed face of said contact layer; and wherein: said first electrode forms an ohmic connection with said current spreading layer; and forms a Shottky diode connection with said Mg + doped window layer.

(10) A light emitting diode in accordance with claim 9 wherein: an opening is formed through said contact layer and said current spreading layer; said first electrode comprises a layer of titanium formed on said current spreading layer and through said opening to contact said Mg+ doped window layer.

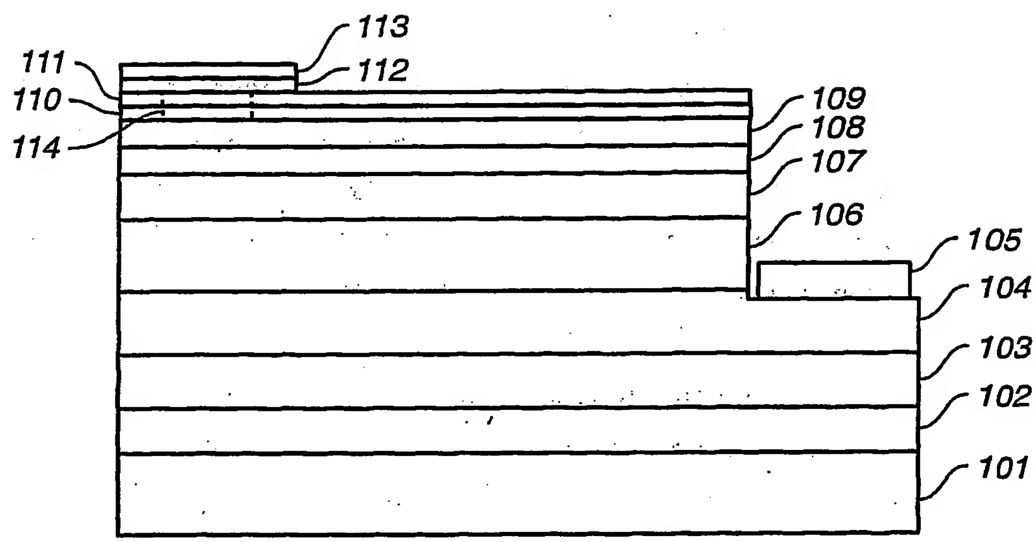

FIG._1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/23346

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :H01L 27/15
US CL : 257/81
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 257/81, 13, 79, 80, 82, 83, 84, 85, 86, 99; 438/606

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,E --- Y,E	US 6,287,947 B1 (Ludowise et al.) 11 September 2001 (11/09/01) see entire document.	1-5, 8 --- 6, 7, 9, 10
Y,P	US 6,225,648 B1 (Hsieh et al) 01 May 2001 (01/5/01) see entire document.	6, 9
Y	US 5,789,768 A (Lee et al.) 04 August 1998 (04/8/98) see entire document.	7, 10

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search	Date of mailing of the international search report
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